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Effect of Temperature on Strength of Concrete

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Abstract: ***This project work deals with the effect of temperature on compressive strength and split tensile strength of concrete. Five different temperatures are considered for this experimental procedure. The specimens are cast and cured at different ages of 7 and 28 days. Specimens are exposed to different temperatures of 28,50 ,100, 150, and 200°C. Mechanical properties such as compressive strength and split tensile strength are studied, the results compared with the results of specimens at room temperature. The results reveal that there is an increase in the strength with increase in temperature.***

Keywords: compressive strength, split tensile strength, residual stress

1. Introduction

Many researchers investigated in different ways about the temperature's effect on concrete by changing different parameters like temperature, curing age, w/c ratio, mix ratio. In this research strength of concrete was investigated based on different temperatures at different curing times

Temperature plays a vital role in investigating the strength of concrete. As the temperature increases it will be having a negative impact on lateral strength of concrete. In previous research it was observed that high initial rate of temperature gives positive impact on initial strength of concrete and gives negative impact on long term strength of concrete

Initial rate of hydration get delayed due to increase in temperature and results in non-uniform distribution of hydration products. This is because of insufficient time available for diffusion of hydration products away from cement particles.

Entering of air becomes highly difficult at higher temperature. In case of lower temperature, the air voids get expand and strength of concrete get reduced. However, entraining agents can be used in large quantities for rectifying this issue. This indicates strength of concrete get disturbed at every temperature.

2. Significance and Use

This research work may help in judging and prescribing the relative changes in concrete design that could be resistible with different temperatures at different curing periods.

3. Preliminary investigations

Introduction

Preliminary investigations are carried out to achieve the required strength of M40 grade concrete. This chapter deals with properties of gradients of concrete mix, various parameters and their effect.

3.1 Justification of Parameters

- **Temperature Range**: Temperature ranges from 50°C to 200°C at an interval of 50°C, most of the situations where concrete is exposed to temperatures are below 200°C and hence this range is selected.
- **Concrete:** Many structures uses standard concrete. Hence M40 grade concrete was used.
- **Age**: It is well established that concrete gains significant amount of strength, 80% of the strength was gained at age of 28 days. 7 days' strength helps in assessing the strength at 28 days.
- **Method of Cooling**: Air cooling
- **Mechanical Properties of Concrete:** Since concrete is strong in compression. along with compressive strength of concrete and split tensile strength is also considered

3.2 Material Properties

3.2.1 Cement: OPC, 53 grade according to IS 12269-1987 with specific gravity 3.14 and compressive strength of 64.5 N/mm^2 is used

3.3. Design Mix

Given Data:

Table 3.3

Materials	Type
Grade of Concrete	M-40
Grade of Cement	Opc-53 Grade
Water Cement Ratio	0.45
Slump	50mm
Admixture	No Admixture Added
Exposure Condition	Moderate
Zone of fine aggregate	Zone ii
Specific gravity of fine aggregate	2.51
Specific gravity of coarse aggregate	2.63

Target strength for mix proportion

$F'_ck = f_ck + 1.65(5)$

$= 40+[1.65 \times 5]$

$= 48.5$ N/mm^2

Let us consider w/c = 0.45

From table 2 IS 10262:2009 maximum water content for 20mm aggregate is 186 liters (for 25 to 50mm slump)

$\frac{w}{c} = 0.45$

$\frac{186}{C} = 0.45$

C = 413.33

Cement content for moderate exposure condition = 410 kg/m^3

410≥320 hence ok

volume of coarse aggregate = 0.62

Volume of fine aggregate content =1 - 0.62 =0.38

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Mix Calculation

a=> Volume of concrete = $1m^3$

b=> Volume of cement = $\frac{\text{Mass of the cement}}{[\text{specific gravity of cement}]\times 1000}$

$= \frac{410}{3.14\times 1000}$

$= 0.130\ m^3$

c=> Volume of water = $\frac{\text{Mass of water}}{[\text{specific gravity of water}]\times 100}$

$= \frac{186}{1\times 1000}$

$= 0.186\ m^3$

Volume of all aggregate = $[a - (b + c)]$

$= [1 - (0.130 + 0.186)]$

$= 0.684\ m^3$

Volume of coarse aggregate = 0.684×0.62

$= 0.424\ m^3$

Weight of coarse aggregate = Volume of coarse aggregate × Specific gravity of coarse aggregate ×1000

= 0.424 × 2.63 × 1000

=1115 kg

Volume of fine aggregate = 0.684×0.38

$= 0.2599\ m^3$

Weight of fine aggregate = Volume of fine aggregate × specific gravity of fine aggregate

= 0.2599×2.56×1000

= 665.344 kg

MIX PROPORTION

Cement = 410 kg/m^3

Water = 186 lit/m^3

Fine aggregate =665 kg/m^3

Coarse aggregate = 1115kg

Cement: Fine aggregate: Coarse aggregate **= 1:1.62:2.71**

4. Methodology

4.1 Introduction

Based on mix proportion cubes, cylinders of concrete are cast and tested in order to investigate mechanical properties of concrete. In this chapter the experimental setup and testing method for compressive strength and split tensile strength are mentioned. The variables for the present study are given below.

4.2 Casting and Curing of Concrete Specimen

4.2.1 Casting of Concrete Specimen

The proportions of the ingredients of the concrete as required are to be specified by from the proportion, by weight used in the test cubes and the unit weight of the materials. The quantities of cement, fine aggregate, coarse aggregate and water for each batch shall be determined by weight, to an accuracy of0·1 percent of the total weight of the batch. All materials shall be weighed and thoroughly mixed by mixer in such a manner as to ensure the greatest possible blending and uniformity in all material. Care being taken to avoid the intrusion of foreign matter before mixing the moulds in layers and compaction is done by vibrator. The specimens demolded after 24 hours from the time of casting.

4.3 Temperature Exposure of Specimen

The specimens are removed from curing tank after completion of desired period of curing of 7/28 days and allowed to dry. The dried specimens are exposed to desire temperatures of say 200°C in the furnace of 300°C for the duration of 1 hour. The exposed specimens are removed and allowed to cool naturally in air. The same procedure is repeated for other temperature of 28,50 ,100, 150, and 200°C.The process of heating of specimens is shown in Fig 3 and Fig 4.

Figure 3: Specimens in oven for exposure

Figure 4: Specimen in furnace for exposure

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4.4 Experimental Setup

Specimens stored in water shall be tested on removal from the water and while introduced at specified temperature. The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is not to the top and bottom the axis of the specimen shall be carefully hanged with the center of thrust of the spherically steel plates no packing shall be used between the faces of the test specimen and the steel plate of the testing machine. As the spherically seated block is brought to bear on the specimen. the movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq mm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted. Specimens were tested as shown in Fig 5 and Fig 6

Figure 5: Cylinder while testing

Figure 6: Cubes while testing

5. Results and Discussions

Introduction

This chapter deals with the results from the experimental investigation for M40 grade concrete are presented. The parameters of study are residual compressive strength and residual split tensile strength at the age of 7 days and 28 days at various temperatures ranging between 50 – 200°c at interval of 50°c

5.1 Effect of temperature on compressive strength of concrete

Residual compressive strength is the compressive strength of specimen expressed as a percentage of 28 days' compressive strength of controlled concrete at room temperature.

The results of the experimental investigation on compressive strength are shown in the table 5.1. The behaviour of effect of temperature on compressive strength of concrete is shown Fig. 5.1, The percentage residual compressive strength increases with increase in temperature within the limits of temperature of study.

Table 5.1: Percentage residual compressive strength at different ages

Age in days	Temperature	percentage residual compressive strength
7	Room temperature	66.9
	50	74.1
	100	80.6
	150	84.7
	200	89.8
28	Room temperature	100
	50	107.1
	100	113.9
	150	119.2
	200	124.5

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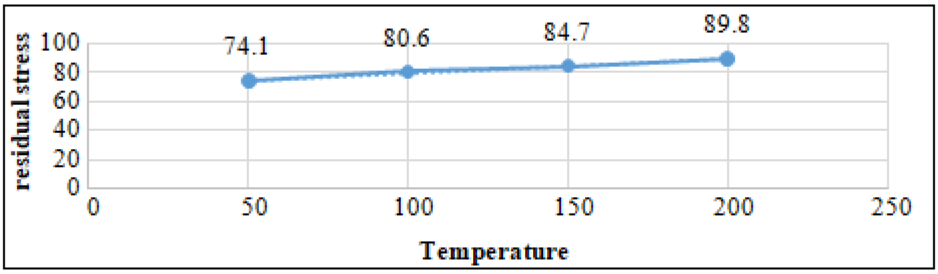

Figure 5.1: Variation of percentage residual compressive strength with temperature at an age of 7 days

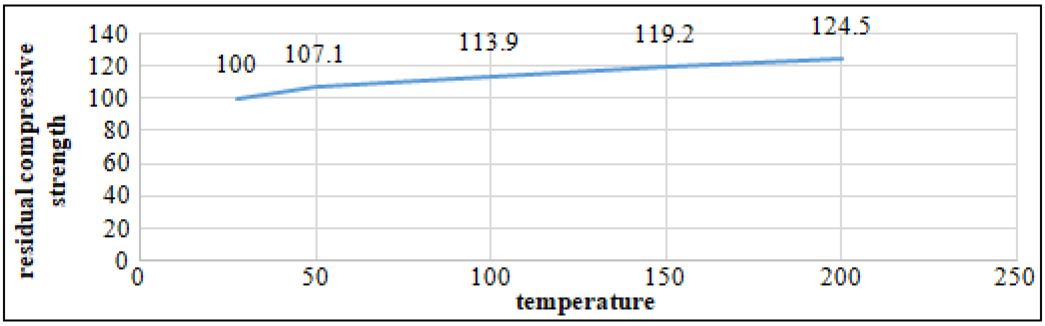

Figure 5.2: Variation of percentage residual compressive strength with temperature at an age of 28 days

5.2 Effect of temperature on split tensile strength of concrete

Residual split tensile strength is the split tensile strength of specimen expressed as a percentage of 28 days' split tensile strength of controlled concrete at room temperature.

The results of the experimental investigation on compressive strength are shown in the table 5.1. The behavior of effect of temperature on split tensile strength of concrete is shown Fig. 5.2, The percentage residual split tensile strength increases with increase in temperature within the limits of temperature of study.

Table 5.2: Values of residual split tensile strength

Age in days	temperature	percentage residual tensile strength
7 days	Room temperature	62
	50	65.5
	100	72.4
	150	82.8
	200	93.0
28 days	Room temperature	100
	50	117.3
	100	120.0
	150	134
	200	137.9

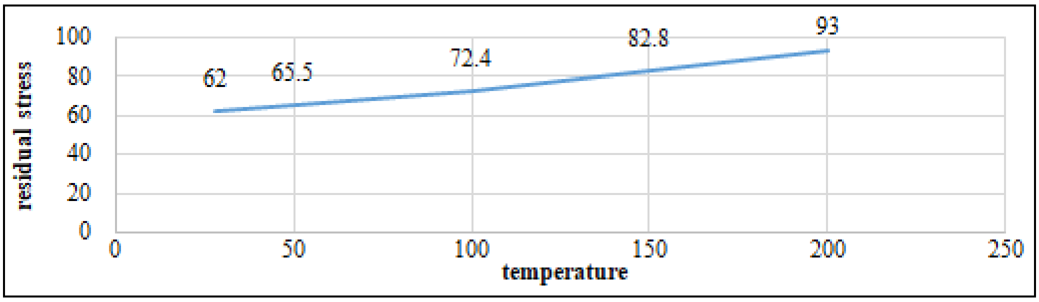

Figure 5.3: Variation of percentage residual split tensile strength with temperature at an age of 7 days

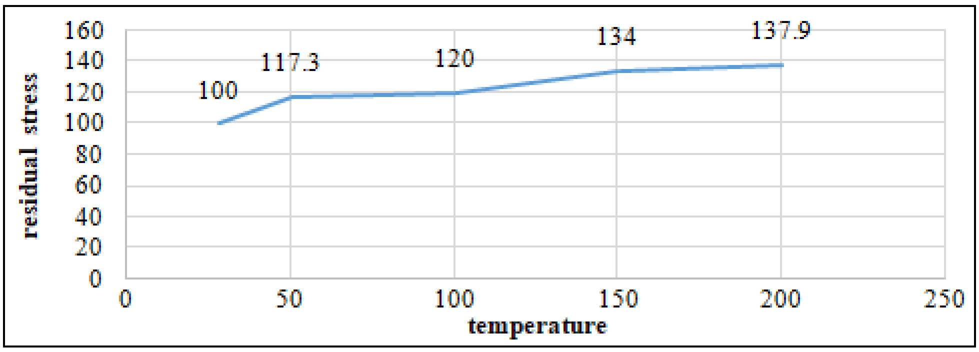

Figure 5.4: Variation of percentage residual split tensile strength with temperature at an age of 28 days

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6. Conclusions

Several structural members are subjected to elevated temperatures, due to high temperature in summer the open places such as pavements etc., and other structural elements are exposed to temperatures. Hence it is necessary to study the behavior of standard concrete at elevated temperatures. In this study the behavior of standard concrete at an age of 7, 28 days exposed to elevated temperatures of 50, 100, 150, 200°C exposed to 1h duration the compressive strength and split tensile strength are investigated and the following conclusions are drawn.

1) Percentage residual compressive strength of concrete increases with increase in temperature
2) Percentage residual compressive strength of concrete increases with increase in age
3) Percentage residual split tensile strength of concrete increases with increase in temperature
4) Percentage residual compressive strength of concrete increases with increase in age.

From the results of investigations of Ashok R. Mundhada, (2015) and H.G Mundel (2014), the compressive strength increases with increase in temperature up to 150°C and start decreasing after 300°C. The interval taken is 150Oc. In between they have not reported. The results of this investigation follow the similar trend of the above investigators.

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